GIS-BASED TEST OF THE CORRELATION OF ANTIMONY AND GOLD MINERALIZATION IN NORTHERN NEVADA

by,

Michelle L. Derenberger

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Thesis Advisor

Douglas Pride, Associate Professor, Geological Sciences

INTRODUCTION

Northern Nevada rocks are windows to the deformation that has occurred throughout geologic time on the western coast of North America. Periods of extension and contraction, as well as, major tectonic orogenies have caused the rocks of Nevada to be folded, faulted and thrust to produce a remarkable diversity. This diversity has spurred people to investigate the results of such widespread deformation. A Geographic Information System (GIS) will be employed to gain insight into the diverse deposits of Nevada with a goal of identifying patterns of mineralization.

This paper will discuss the occurrence of gold (AU) and silver (AG) deposits in northern Nevada. The occurrence of these deposits will be compared with the terrane in which they occur and also with the mineralogical species of antimony in each deposit. The first portion of this paper will examine the regional geology of northern Nevada (Figure 1). The second portion will introduce the analytical techniques necessary to manipulate a data base to obtain results capable of being utilized by a Geographic Information System (GIS). Lastly, a discussion of the results will be performed to express any correlations that may have occurred between metal deposits, terrane and mineral species of antimony.

REGIONAL GEOLOGY

Structure

Approximately 850 m.y. ago, in the Late Proterozoic, a period of rifting and subsidence produced a large shelf on the western paleocoast of North America.[1] From the time of deformation to the Late Devonian, thick sequences of

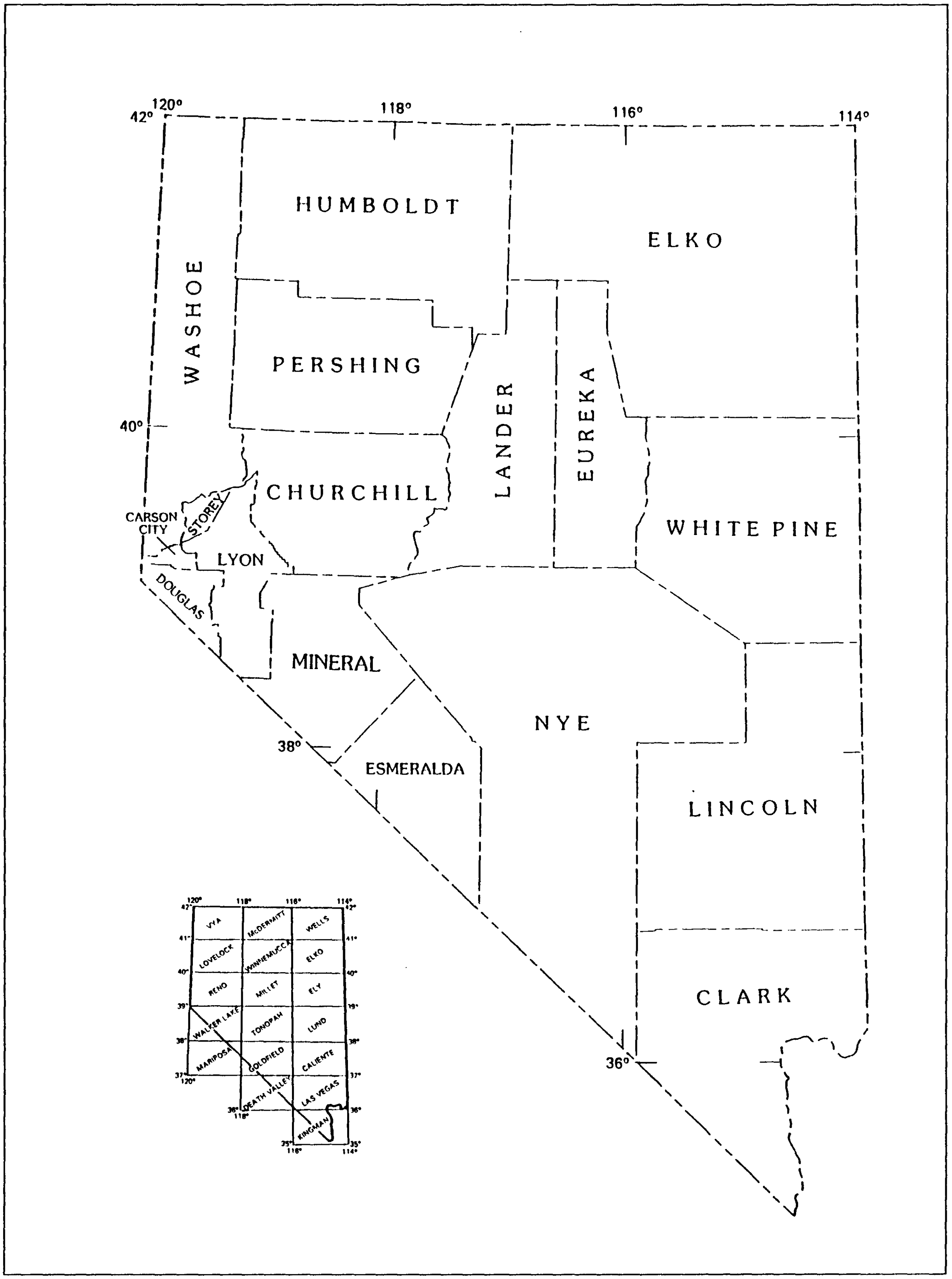

Figure 1. Nevada

terrigenous siliciclastic and carbonate sediments accumulated. These sediments produced a massive wedge that thinned landward and covered what is now western Utah and eastern Nevada (Figure 2). The Antler orogeny occurred during the Late Devonian and Early Mississippian (Figure 3 and 4). During this period, the Roberts Mountain allochthon was thrust eastward onto the continent approximately 140 km.[2] The allochthon placed lower Paleozoic continental rise and ocean floor sediments above time-equivalent continental shelf deposits. The thrust of the allochthon onto the continent produced a north-trending belt of highlands that were locally subaerial through the Pennsylvanian. Flysch deposits of greater than 1500 meters were deposited in the subsiding Antler foreland basin prior to the Mississippian.[3] Molasse sedimentation began during the middle Mississippian.[4] Shallow marine deposits were emplaced on both the eastern and western flanks of the allochthon and were deposited beginning in the Middle Pennsylvanian. These sediments were termed the overlap assemblages.[5] Prevalent erosion occurred throughout the Middle and Late Pennsylvanian and is marked by a regionally far-reaching unconformity at the base of the Upper Pennsylvanian shallow marine rocks. After the period of erosion, shallow-marine sedimentation began again until it was interrupted by the Sonoma orogeny during the Triassic. The Sonoma orogeny pushed deep water strata, of the Upper Paleozoic, eastward onto the Roberts Mountain allochthon and its adjacent sediments.[6] This allochthon was termed the Golconda.[7] Shelf sediments were deposited on the allochthon and grade westward into basin sediments. From the Jurassic to Paleocene, three "thin-skinned" thrusts occurred in Nevada and Utah, these were the Sevier belt of eastern Utah, the Eureka belt of central Nevada, and the Winnemucca belt of western Nevada. Later in the Jurassic, during periods of extension, Triassic basin sediments were thrust over the Triassic shelf sediments by the Fencemaker thrust.[8] This occurred again by the Willow Creek thrust. Both

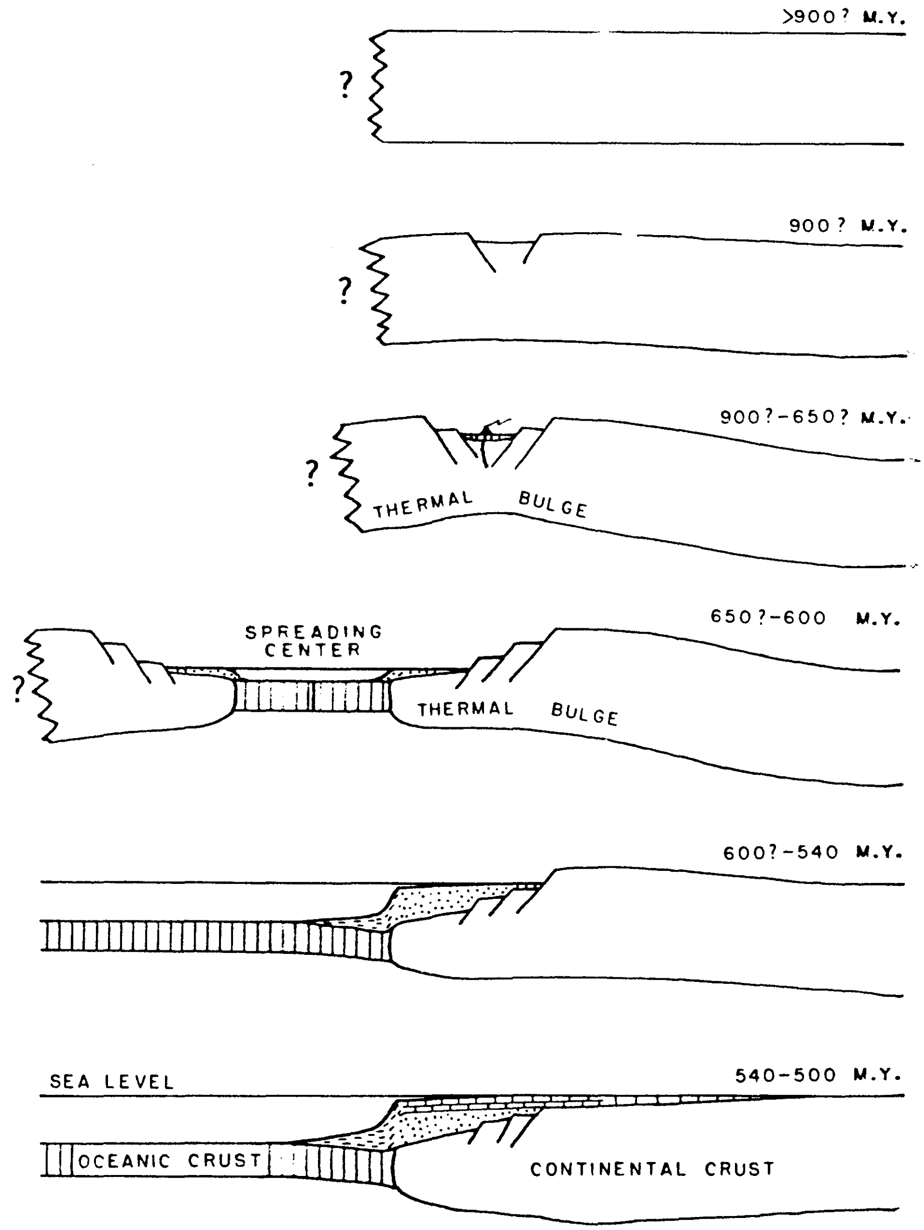

Figure 2. Model of late Precambrian and Cambrian deformation in the western United States.

Source: Stewart and Suczek, 1977.

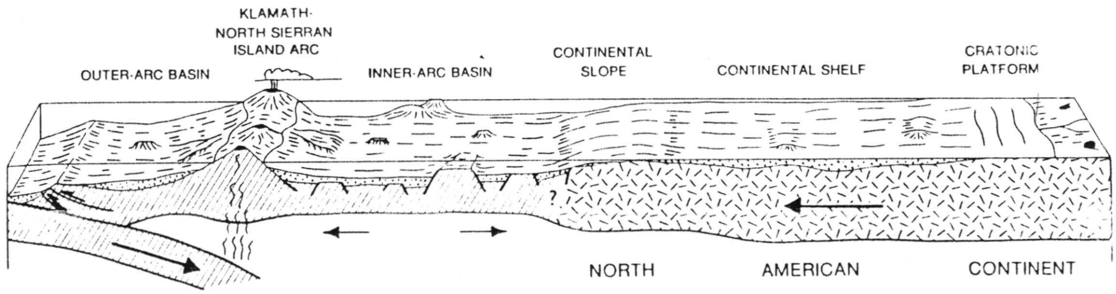

Figure 3. Model of Silurian and Devonian island-arc system.

Source: Poole and Sandberg, 1977.

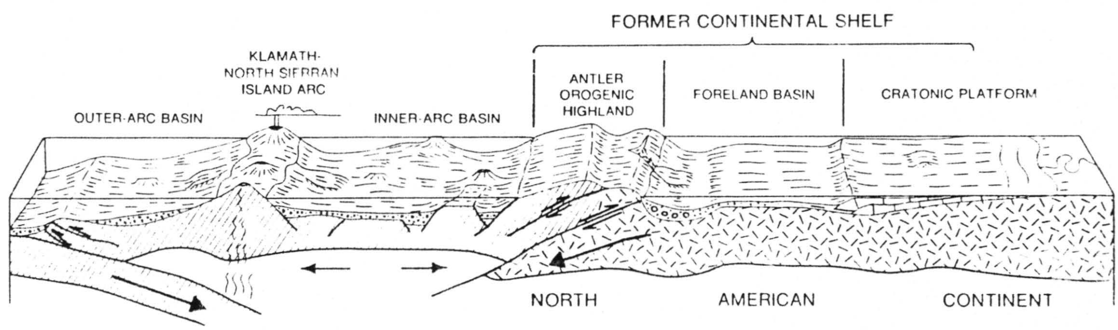

Figure 4. Model of late Devonian and Mississippian island-arc systems during the Antler orogeny.

Source: Poole and Sandberg, 1977.

the Fencemaker and Willow Creek thrusts are part of the Winnemucca deformation belt.[9] The Fencemaker and Willow Creek divide the the belt into three north-south trending units, the Fencemaker allochthon, the Winnemucca belt autochthon, and the Willow Creek allochthon (Figure 5). Figure 6 represents the formations present in the Winnemucca belt and their relations to the adjacent areas. The Tertiary period is characterized by widespread volcanism and normal faulting from Basin and Range extension.[10]

Stratigraphy

The oldest Cambrian rocks that are found over large areas of Nevada are called the Prospect Mountain quartzite. Deposits in eastern Nevada, and of Middle to Late Cambrian age are typified by deposits found at Eureka. They consist mainly of limestone and dolomite with some interbedded shales and quartzite and are about 15,000-20,000 feet thick.[11] Middle to Late Cambrian rocks of western Nevada are markedly different than those of the east. Three formations are used to represent the western lithologies - the Scott Canyon Formation, the Paradise Valley Formation and the Harmony Formation. The Scott Formation is found in the Battle Mountain area and is composed of approximately 5,000 feet of radiolarian chert, argillite, and greenstone, with small amounts of sandstone, quartzite and limestone.[12] The Paradise Valley Chert and Harmony Formation are exposed in north-central Nevada. The Paradise Valley Chert is composed of chert, thinly-bedded, chert breccia with some shale and limestone present.[13] The Harmony Formation overlies the Paradise Valley Chert and is also exposed in north-central Nevada. The Harmony is made up of feldspathic sandstone and siltstone, with shale and some limestone and pebble conglomerate. The formation ranges is thickness from 600 to 1,300 feet.[14] The Scott Canyon,

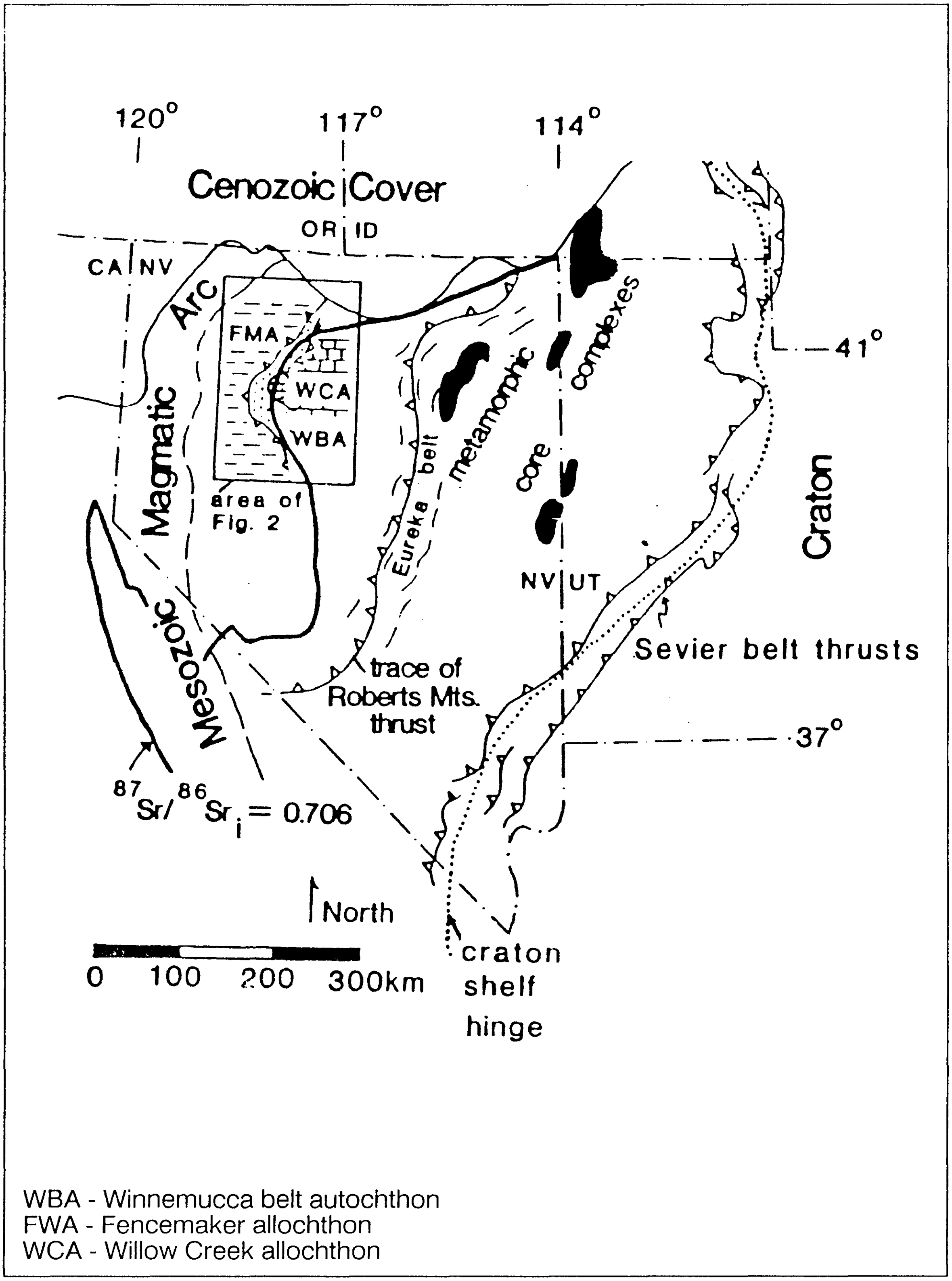

Figure 5. Location of the Winnemucca deformation belt.

Source: Elison, Speed and Kistler, 1990.

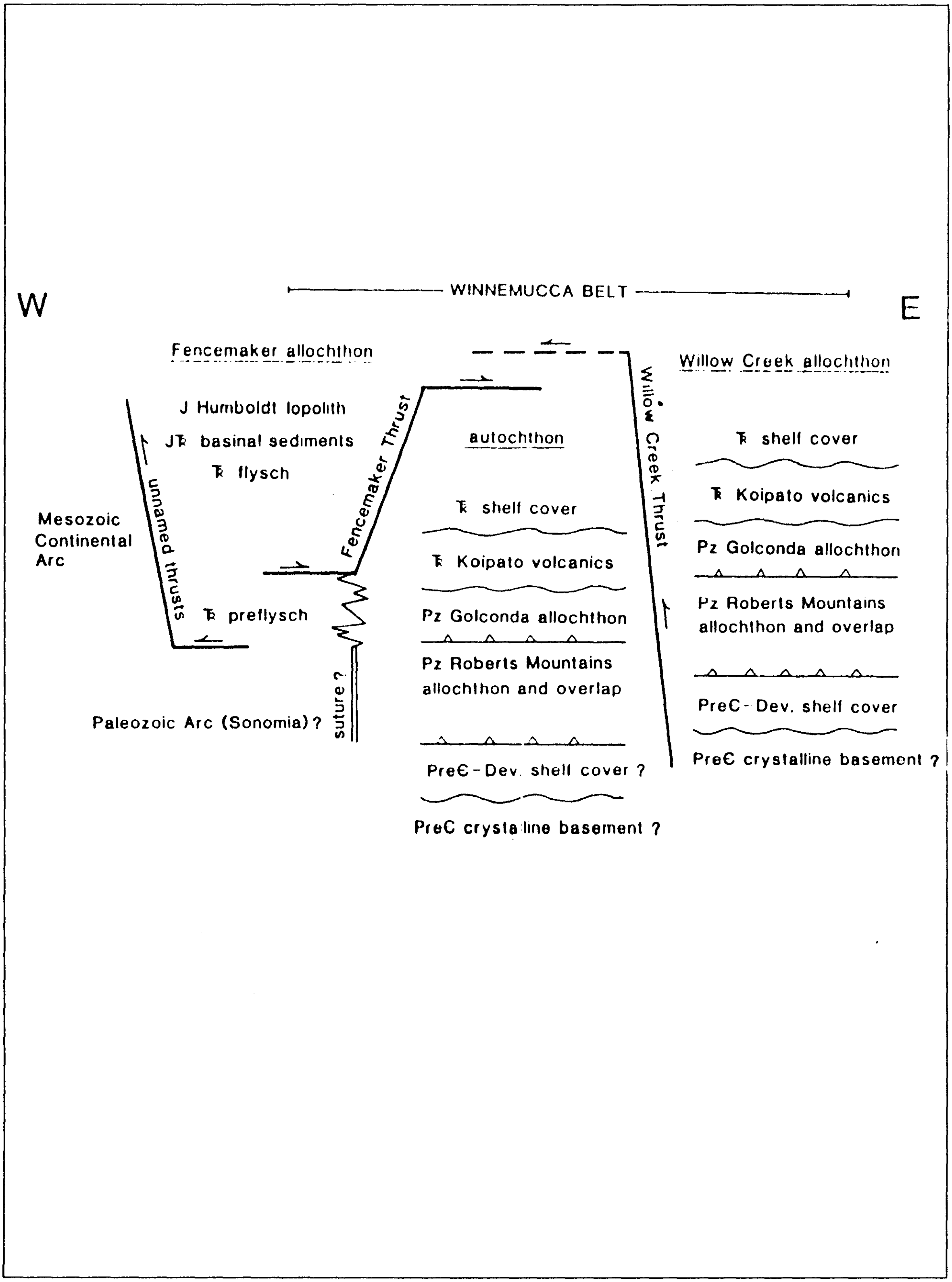

Figure 6. Tectonostratigraphic stacking diagram of the Winnemucca belt.

Source: Elison, Speed and Kistler, 1990.

Paradise Valley and Harmony Formations are all considered to be eugeosynclinal deposits.

The Ordovician was a time of tectonic quiescence when the sediment was mostly carbonate and siliciclastic. The eastern Nevada deposits, such as Western Peak in the Roberts Mountain window are typical of Ordivician deposits and consists of approximately 350 feet of thinly bedded limestone. The Eureka quartzite is about 500 feet thick and is a white, vitreous quartzite that unconformably overlies the Western Peak limestone. Approximately 560 feet of the Hanson Creek formation overlies the Eureka. The Hanson consists of dark gray dolomite.[15] The deposits of the Ordovician were believed to have been deposited in a miogeosynclinal environment.

Silurian and Devonian deposits in western Nevada consist of thin-bedded chert, mudstone, siltstone, limestone, volcanic rocks and some sandstone and conglomerate. Eastern Nevada was at the continental shelf and contains thick deposits, approximately 2,500 meters, of limestone, dolomite and some sandstone and siltstone. Transitional deposits are about 1,500 meters of thin bedded limestone and siltstone with some sediment gravity flow deposits. These were probably deposited at the continental slope.

After the Antler of the Mississippian, a foreland basin developed east of the highlands. A deep and rapidly subsiding trough at the western edge of the basin contained flysch deposits from the highlands, while the eastern part of the basin was being starved of terrigenous sediments. Western deposits were initially calcareous siltstone, until another tectonic pulse began depositing flysch.

Eventually, thin layers of phosphatic mudstone and siltstone where deposited in the eastern foreland basin.

Triassic strata, in northern Nevada, is divided by the Fencemaker thrust. The sequence of rocks east of the Fencemaker thrust are dominated by shallow-water limestone and dolomite, interbedded with siltstone, mudstone, siliciclastic sandstone and local chert pebble conglomerate, all of the Star Peak Group. The Star Peak Group was characterized as as progradational carbonate platform that was interrupted by regressive and transgressive periods.[16] Overlying the Star Peak Group are the Grass Valley, Dun Glen and Winnemucca Formations. The Grass Valley was interpreted as a deltaic complex and consists of interbedded siliciclastic sandstone, siltstone and mudstone. The Dun Glen is more similar to the Star Peak Group and was determined to be carbonate platform deposits consisting of shallow-water limestone and dolomite. In contrast, the Winnemucca Formation contains siliciclastic and carbonate strata that might have been deposited on a narrow shelf.[17] The rocks west of the Fencemaker thrust are not as easily correlated. They are mostly siliciclastic mudstones and channelized sandstones overlain by hemipelagic carbonates. These deposits are then overlain by repeating sequences of siliciclastic mudstones, etc. These strata were considered to have been deposited on a migrating fan near the base of the slope.[18] An overall interpretation of Triassic sediments suggest that the carbonate platform of the Star Peak Group extended westward over the Golconda allochthon. An influx of siliciclastic sediments from the east, buried the platform and the sediments were deposited in a deltaic complex. The sediments from the shelf, fell over the shelf-slope break and accumulated in submarine fans at the base of the slope.[19]

Tertiary metamorphic core complexes are characterized by high topographic expression but a moderated sized outcrop. The complexes are deformed and metamorphosed igneous and sedimentary rocks. The decollement separates the crystalline core from the unmetamorphosed and deformed cover. Granitic plutons and pegmatites are common basement terranes.

ANALYTICAL PROCEDURES

Mineral Resources Data System (MRDS)

The MRDS data base was produced by the United States Geological Survey (USGS) and details mineral deposits and occurrences. The data was gathered during routine USGS mineral resources studies and concentrates on commodity and geologic data for mineral deposits that are most useful for such purposes as exploration and resource assessments.[20] Nearly 85,000 deposit and occurrence records are available from the data base, with each record containing approximately two hundred data fields.

The data base was used for this paper to determine the type of deposits occurring in northern Nevada and the antimony mineralogy in these deposits. Four hundred and nineteen deposits or occurrences were found in Nevada. Of those, two hundred and fifty-seven were located in northern Nevada (north of 39^{o} latitude).

Field 38, Commodities Present, in the data base was used to classify the deposits into the following types: AU, AG, HG, W, CU, BA, AS, SB and Others. Gold was considered the most economically important mineral. Silver was considered the next important, but was divided into two groups - AG with PB, CU, ZN and AG without PB, CU, ZN. The decision trees for determining deposit types are located in Figure 7. Table 1 is a summary of the classification codes assigned to each deposit and Table 2 represents the number of deposits corresponding to each classification. It was discovered during use of the data base that certain records contained mineral "codes" that were accompanied by a question mark. These codes were not considered in the determination of deposit type because the intended purpose of the mark was not understood.

Ore Materials, field 39, was used to determine the mineralogy of the antimony occurring in the deposits. Stibnite and antimony sulfosalts were of major concern, although antimony oxides were also considered. The decision tree for antimony mineralogy is located in Figure 8. Table 3 is a summary of assigned values and Table 4 the number of values within each classification. Misspellings and "unknowns" were encountered during the use of records in this field. If minerals could be determined by available spelling than they were considered, those that could not be determined or that could not be located in available mineralogy reference texts were not considered. When "unknown" was encountered with an accompanying code it was determined that the author had knowledge of minerals mined or occurring that could not easily be found in hand specimen. Those "unknowns" that did not have a code were listed as "other or unknown mineralogy".

Fields 34 and 35, Latitude and Longitude, were cross checked with fields 22 and 23, UTM, to determine if any errors existed in either set of fields. Fifteen records were discarded because the differences in UTM and latitude and longitude were greater than one kilometer. Thirteen of the records were duplicated by having

1. Is AU present?
    Yes? Go to 2.
    No? Go to 6.
2. Is AU presented with a question mark?
    Yes? Go to 6.
    No? Go to 3.
3. Is AU present with AG?
    Yes? Go to 4.
    No? Assign value 1.
4. Is AG accompanied by atleast two of the following - CU, PB, ZN?
    Yes? Assign value 2.
    No? Go to 5.
5. Is AG listed before AU?
    Yes? Assign value 3.
    No? Assign value 1.
6. Is AG present?
    Yes? Go to 7.
    No? Go to 8.
7. Is AG accompanied by atleast two of the following - CU, PB, ZN?
    Yes? Assign value 2.
    No? Assign value 3.
8. Is HG present?
    Yes? Go to 9.
    No? Go to 10.
9. Is HG > > SB?
    Yes? Assign value 4.
    No? Assign value 5.
10. Is W present?
    Yes? Go to 11.
    No? Go to 12.
11. Is W > > SB?
    Yes? Assign value 6.
    No? Assign value 7.
12. Is CU present?
    Yes? Go to 13.
    No? Go to 14.
13. Is CU > > SB?
    Yes? Assign value 8.
    No? Assign value 9.
14. Is BA present?
    Yes? Go to 15.
    No? Go to 16.
15. Is BA > > SB?
    Yes? Assign value 10.
    No? Assign value 11.
16. Is AS present?
    Yes? Go to 17.
    No? Go to 18.
17. Is AS > > SB?
    Yes? Assign value 12.
    No? Assign value 13.
18. Is SB present?
    Yes? Assign value 14.
    No? Go to 15.
19. All other minerals assign value 255.

Figure 7. Decision tree for deposit type.

TABLE 1. SUMMARY OF CLASSIFICATION CODES

MINERALOGY	CLASSIFICATION CODE
AU	1
AG (w/PB, CU, ZN)	2
AG (w/o PB, CU, ZN)	3
HG>>SB	4
HG<<SB	5
W>>SB	6
W<<SB	7
CU>>SB	8
CU<<SB	9
BA>>SB	10
BA<<SB	11
AS>>SB	12
AS<<SB	13
SB	14
other	255

TABLE 2. NUMBER OF OCCURRENCES PER CLASSIFICATION

CLASS NUMBER	NUMBER OF OCCURRENCES
1	45
2	81
3	51
4	9
5	3
6	5
7	3
8	3
9	3
10	3
11	2
12	1
13	2
14	19

1. Is stibnite present?
    Yes? Go to 2.
    No? Go to 4.
2. Are antimony sulfosalts present?
    Yes? Go to 3.
    No? Go to 7.
3. Are antimony oxides present?
    Yes? Assign value 1.
    No? Assign value 2.
4. Are antimony sulfosalts present?
    Yes? Go to 5.
    No? Go to 6.
5. Are antimony oxides present?
    Yes? Assign value 3.
    No? Assign value 4.
6. Are antimony oxides present?
    Yes? Assign value 5.
    No? Go to 8.
7. Are antimony oxides present?
    Yes? Assign value 6.
    No? Assign value 7.
8. All other antimony-bearing minerals or unknowns assign value 255.

Figure 8. Decision tree for antimony mineralogy.

TABLE 3. SUMMARY OF CLASSIFICATION CODES

MINERALOGY	CLASSIFICATION CODE
SB/SS/O	1
SB/SS	2
SS/O	3
SS	4
O	5
SB/O	6
SB	7
other	255

TABLE 4. NUMBER OF OCCURRENCES PER CLASSIFICATION

CLASS NUMBER	NUMBER OF OCCURRENCES
1	6
2	23
3	9
4	13
5	10
6	34
7	60
255	72

identical latitudes, longitudes, (or UTM), deposit types, and mineralogy. Two additional records were duplicated by having adjoining locations and containing the same deposit type and mineralogy. After removing the duplicated and erroneous data records, two hundred and thirty-seven records remained.

Geographic Information Systems (GIS)

Panasea, a raster based system, was the GIS used for this paper. The UTM coordinates were taken from the MRDS data base and entered into Panasea. Each set of coordinates was accompanied by a code for both the deposit type and the antimony mineralogy. To properly locate the points onto a map of northern Nevada, the four corners of the study area were digitized into the system along with their latitudes and longitudes. The metal deposits were then capable of being placed in an overlay, showing their locations in reference to the state borders. To further study the relation of the occurrences of the metal deposits to known terranes, a metallogenic map was digitized to show the boundaries of the following terranes: the Roberts Mountain, the Golconda, the Junga, the West Lake, the Jackson and the continental shelf. The deposits were then placed on an overlay with the terranes to look for possible correlations. Overlays were completed that show where AG and AU occur and the characteristic mineralogy of each.

RESULTS

Plate 1 representing the deposit type and Plate 2 representing the antimony mineralogy can be found in Appendix B. After viewing the plates it is obvious that a trend in occurrences is not readily identifiable.

DISCUSSION

Table 5 represents the occurrences of AG and AU in the area of study and calculates the ratio of AG:AU in each of the designated terrane. The ratio remains relatively continuous throughout the Roberts Mountain, Golconda and Jungo Terranes.

Table 6 shows the type of antimony mineralization in each terrane, as well as, the ratio of SB:SS. A trend is obvious from the Roberts Mountain Terrane to the Jungo Terrane, showing a decrease in stibnite occurrences.

It is unclear how the differences in formations, metamorphism, etc, experienced in each terrane, effect the occurrences of AG and AU. It is also unclear why the amount of stibnite mineralization decreases from east to west. Each of these areas need to be studied more closely using GIS.

TABLE 5. COMPARISON OF TERRANE AND AG/AU RATIO

TERRANES AND CLASS		NUMBER OF OCCURRENCES	RATIO OF AG:AU
Westlake			
	AG	9	9.0
	AU	1	
Jackson			
	AG	15	1.9
	AU	8	
Jungo			
	AG	60	3.16
	AU	19	
Golconda			
	AG	30	3.0
	AU	10	
Roberts Mountain			
	AG	11	2.2
	AU	5	
shelf			
	AG	13	6.5
	AU	2	

TABLE 6. COMPARISON OF TERRANE AND SB/SULFOSALT RATIO

TERRANES AND CLASS		NUMBER OF OCCURRENCES	RATIO OF AG:AU
Westlake			
	SB	5	5.0
	SS	1	
Jackson			
	SB	9	3.0
	SS	3	
Jungo			
	SB	44	1.52
	SS	29	
Golconda			
	SB	20	2.0
	SS	10	
Roberts Mountain			
	SB	11	2.2
	SS	2	
shelf			
	SB	5	.83
	SS	6	

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APPENDIX A